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APPLIED BIOLOGY

MOST laymen seem to imagine that men of science pursue their subject because of the practical ends in view. Science, as reflected in the popular press, would appear to be a modern version of Santa Claus. Surrounding herself with a good deal of complicated apparatus and appropriate laboratory odors to give the atmosphere of the magician, she is busily engaged in devising telephones, aëroplanes, miraculous cures for disease, new forms of vegetables, radio sets, elixirs of life, and other trifles of which the rest of mankind can make use. That is her *raison d'être*, and the hope of serving the community by presenting it with a new toy which really works is the scientist's inspiration and the mainspring of his work.

Such a picture is singularly far from the truth. The man of science pursues knowledge because to him the pursuit of knowledge and the discovery of new truth are the breath of his nostrils. He devotes himself to research for precisely the same reason that the poet devotes himself to the arduous business of writing poetry, the explorer to the dangers and hardships of unknown lands, the mystic to the time-consuming rigors of the devotional life, or the mother to the never-ending service of her child. He is reasonably content with a salary which a civil servant or business man of the same calibre would laugh at, he is often prepared to work in the laboratory all day and spend his evenings in the labor of reading or writing—Why? Because the

discovery of new knowledge is what above all else interests him, what alone gives essential value to his work.

He is not, to be sure, uninfluenced by considerations of practical utility. The poet hopes that other men will read his poems and thereby come to richer life; the explorer doubtless reflects that his new lands may be colonized; the mystic believes that his ecstasies help and inspire in the business of every day; and the mother wishes her child to grow up a useful member of society. But mothers may still love their children when they are puny and weak, when they are stupid or base, when they grow up to vice or crime. They love because not to love would be to repudiate their own natures.

And it is so with the rest of my examples. Not to attempt what he is attempting would be to each a renunciation of the best part of himself, a burial of his one talent wrapped in the napkin of opportunism.

To many that will be a hard saying: but it is true for all the highest activities of human nature. They are pursued as ends in themselves, for their own values, which are above the values of the so-called practical life of every day.

Luckily, however, the world is so constructed that practical results do flow from knowledge, for whatever reason that knowledge may have been pursued. That this is so is a part of the essential reasonableness of life—its different parts do cohere, however difficult it may sometimes be for us to see the connection. Examples are infinite. Galvani fiddling about with frogs' muscles and strips of metal, Faraday in his dingy basement at the Royal Institution—without them you would to-day have no electric light, no telephone, no dynamo. Newton's apple is probably mythical, but, certainly, without his passion for understanding the courses of the stars, we should be without the nautical

almanac; without his devotion to pure mathematics, the calculus would have been far slower in its coming, and the whole progress of science would have been different and feebler. And without poetry and music and other art, life to many would be hardly worth living. No need to multiply instances: it is enough (though that for most men seems hard!) to understand that life from highest to lowest manifestations is one, that to despise or belittle any part of it is wrong and foolish. It is as foolish to belittle pure science because it is unpractical, or poetry because it is visionary, as it is to despise the body because it is not the soul, or be contemptuous of the common man because he is not the uncommon man. Love flowers out of simple sex; art out of everyday emotions; mind depends on brain, and brain on food and drink. It is a too common sign of mediocrity and false culture to disbelieve in the values of what is higher than itself, and at the same time to despise and try to put out of sight the lower things which are yet the foundations on which it is built. Philistinism and snobbery, narrow-mindedness and prudery—they all go together.

But to the business in hand! Science advances by the search for knowledge for knowledge's sake, but the knowledge spills over into practice as the years advance. Our business is to see how in recent years biological knowledge has been applied to practice, and what new advances may be expected.

The first spectacular applications of modern biology have been in the realm of disease-prevention. Pasteur followed up his final demonstration that spontaneous generation does not occur with the discovery of its corollary—to wit, that infectious diseases, such as typhoid, diphtheria and pneumonia, were caused by living organisms, or, as they are sometimes styled, disease germs. Most of these

so-called germs belong to the bacteria, the simplest known organisms, capable of multiplying two or three times an hour. Modern research has shown that some others, like that of measles, are ultra-microscopic, too small ever to be seen. Still others are of animal nature, like the active causes of malaria and sleeping sickness.

Hand in hand with this went our knowledge of parasitology. In the first place the life-histories of many of our larger parasites were unravelled, with the result that it has been possible in many cases to break the weak link in the life-chain and to stamp out that particular disease and discomfort. That is true in civilized countries for tapeworm, roundworm and trichina: and the hookworm and other enemies of the fullness of human life are following in their wake. But later it was found that there was frequently an association between some parasite or other noxious animal and the microscopic agent of some disease. Rats harbor fleas of a particular sort, the fleas harbor the bacilli of plague, and so is plague spread throughout mankind. Ticks spread spotted fever, mosquitoes give malaria and "Yellow Jack", flies may infect our food and our persons in a dozen ways.

So arose what for brevity's sake may be called the germ theory of disease. Any given disease was supposed to be due to a given organism, large or small, animal or plant: if you could exterminate or weaken the germ, you could get rid of the disease. The triumphs of serum-therapy—vaccination, and other forms of immunization—again largely due to Pasteur and later to Ehrlich, showed how the enemy might be circumvented even when it was impossible to annihilate him: and a period of optimism dawned.

The germ took hold of scientific and popular imagination alike. To medicine, the problem of disease seemed

enormously simplified. Disease became something extraneous, to be fought and killed: bacteria were simply the enemy. The popular mind took this idea and clothed it to suit its own taste, as it clothed mediæval Christian theology. Germs, instead of the dull-looking rods and dots of bacteria that they really are, became microscopic monsters, scientific devils: but in the popular mind, too, the germ-theory revived in matters of health the old crude ideas of external warring powers of good and evil.

The particular brand of optimism based on the germ-theory is passing away. The pioneers had forgotten that as it takes two to make a quarrel, so it takes two to make a disease. They had left out of account the human organism.

We now know that the reaction of the organism is as important as the nature of the parasitic "germ". We all of us seem to harbor the bacillus of tubercle: but only a small percentage develops tuberculosis. Measles, with us an unpleasant disease of childhood, wiped out whole populations when first introduced among the South Sea Islanders. Why? Because their natural inborn resistance was less than ours. We now know that to every disease-germ there are very different grades of inborn resistance, and further, that any of these grades may be increased or lowered by outer circumstances.

While some diseases may, therefore, be totally eliminated by the extermination of the disease-germ itself, or, more usually, by breaking a link in the chain by which the germ is transmitted, there are others in which, so far as we can see, it will forever be impossible to destroy the microscopic and elusive bacillus; and, if we wish to prevent and not merely to cure, we have to rely on the raising of resistance.

The first method has, however, had its notable triumphs. Malaria, smallpox, yellow fever, bubonic plague, sleeping sickness—there we have a few of the plagues which have been almost expelled from the civilized world and will slowly but surely fade from the uncivilized as well.

This method of control by extermination can be extended not only to larger parasites, but to all animals noxious to man. Given time and a little trouble, we could make for ourselves a world without centipedes, tarantulas, scorpions, biting insects and poisonous snakes as effectively as the United States Health Service has rid the Panama Canal zone of the microscopic organisms of malaria and yellow fever.

As an example of what may be done in the economic field by intelligent control, we have only to look at the past and present of the gipsy moth. A couple of weeks ago I was motoring along Cape Cod. Dead trees were standing everywhere in the woods. My host told me that these had been killed by the gipsy moth. Not only that, but for some years there were no leaves on any tree in all that neighborhood, and the caterpillars came down, when they had stripped the trees, to eat the grass and flowers. On a still day the woods were full of a sinister rustling—the munching of a million jaws, and rattle of the million pellets of undigested food continuously extruded by the destroying army. Hundreds of thousands of dollars a year were spent by the State in spraying and other curative measures: but with only meagre results. Eventually biology came to the rescue. Entomologists studied the gipsy moth in its original home and discovered just what natural enemies it had there. They imported these enemies—a beetle that devours the eggs, another, larger, which attacks the caterpillars, and a hymenopteran whose brood, deposited as eggs in the caterpillar, devours the growing animal from the interior.

These keep the gipsy moth in check, so that to-day the countryside is green again, and the moth, though not exterminated, is become only a minor annoyance. Without the meticulous knowledge of the ways and life-histories of a thousand and one apparently useless beetles and flies and moths, amassed often just for the sake of knowing, such control could never have been accomplished.

But to return to the other side of the picture. The discoveries of variability of resistance have in the last few years become linked up in the most interesting way with work in nutrition and work on the effects of light.

As every educated person now knows, it has recently been shown that certain substances which we call vitamins are necessary in our food if health is to be maintained. We can be given diet which is apparently ample in every way for all our requirements of repair and energy, but in the absence of vitamins we cannot utilize it. What exactly and chemically they may be we do not yet know; we know that they are necessary, and where they are to be found. Some years ago, it was apparently demonstrated that rickets, that scourge of slums, was what is called a deficiency disease—a disease due to lack of vitamins. Animals could be made to develop rickets by depriving them of one particular vitamin, and could be cured again by supplying the deficiency. Cod-liver oil was found especially potent in its curative properties; and, as a result of this discovery, cod-liver oil in shiploads has been used to set the undernourished population of Vienna literally on its legs again.

But investigation proceeded; and the story turned out not to be so simple as we had supposed. Of animals kept on a diet with a minimal quantity of the vitamin, those which were kept indoors in dark rooms and crowded cages would develop rickets, those kept outdoors in the light and

with opportunity for exercise would not. Exercise and especially sunlight could, it seemed, replace the vitamin.

On my way down here I visited the University of Wisconsin. There Professors Hart and Steenbock are carrying the matter a step further. They are finding that a great number of substances which normally are useless in preventing rickets can be made effective by a short exposure to sunlight or to artificial ultra-violet light. Their belief is that some inactive substance is activated, turned into the active vitamin itself, by the rays of light. Meanwhile workers in other lines have been exploring the possibilities of light. They have found that ultra-violet light, whether in the light of the sun or generated artificially in the laboratory, has the most remarkable effects. It heightens the natural resistance to infection, it alters the blood pressure, it tones the skin, it stimulates growth. Miraculous effects, particularly with children, are being obtained in hospitals all over the world with light treatment. Slum children, tuberculous, emaciated, pale, rickety, with ulcers and sores upon them, come for a month or two to such places as the Treloar Hospital in the country near London, and go back vigorous and healthy.

When to the radiant energy of light is added a cool temperature, as at high altitudes in the mountains, the effects are even more remarkable. This was first demonstrated by Rollier in Switzerland; and Professor Hill of London has explored some of the underlying physiology of the process.

Civilization is thus correcting its own mistakes. In its blind hurry it aggregated thousands after thousands of human beings in cities. To house them cheaply it erected tenements; to feed them simply it sent in canned food; to save trouble or money, it let a pall of smoke hang over

them; to save space, it cooped them up without sufficient room to stretch their limbs or play.

And in so doing it excluded the light of the sun from their life and the vitamins from their food, and thus stunted their growth and lowered their resistance to disease. Now the wheel comes full circle. We see what we have done; but there is a world of harm to undo.

The moral of all this is plain to see. We can do a great deal to ameliorate human suffering by getting rid of tangible enemies to health; but that is not enough. Remove all the living enemies to health in the world, all the germs, all the parasites, all the venomous creatures: and men will not necessarily be healthy. Health is a living, active principle which needs fostering on its own account. It is like a plant: it is not enough to keep the children from trampling on it and the goats from nibbling it down; it must have its own power of growth within it. And the necessities for active health come back to the simplest and most fundamental things—diet, bodily exercise, air and light, and mental interest. Body and mind must be used, the gifts of sun and wind not despised, and food and drink be properly regulated in quality and moderated in amount.

It all sounds so simple: but to be simple does not necessarily mean to be easy! At least, however, we are released from the false optimism of the germ-theory period, and reminded that healthy living, like all living worth the name, is an art. We can simplify the practice of it, but at the end we must bestir our individual selves to attain success. Medicine is still groping for the cause of cancer: but even with cancer it will probably be found that a rational life will do more to prevent it than any specific measures, in just the same way that cleanliness, good food, well-built houses and good sanitation have done quite as much to banish

smallpox, leprosy or plague as have vaccination, segregation, or the deliberate destruction of rats. In any case it is safe to prophesy that medicine will tend more and more to become preventive instead of curative—a tendency which will involve a radical change of status and outlook among the medical profession.

So far we have spoken of biology in relation to the health of the individual: now we have to discuss its bearing on the health of the race.

Two problems confront us, the one immediate and pressing, the other more complex and less instantly urgent. They are the problems of birth-control and of eugenics. Let me remind you at the outset of some elementary facts, of some of which I spoke in my first lecture. The continuity of the human race, like that of all organisms, is assured by a continuity of actual substance. The child is produced by the growth of a portion of living matter which once formed part of the parent. In all higher animals there is sexual reproduction—the child has two parents, and each contributes a living share. These contributions are cells, the *gametes* or marrying cells—the ovum or egg from the mother, the sperm from the father. The hereditary constitution is part of the gametes. It is that which determines the main lines of development; and it is given, irrevocably, at the moment of union of the two gametes and consequent origin of the new individual. To be sure, the environment also has its molding effect; but the effects of heredity are more deep-seated. Differences between people may thus be due to differences in their hereditary constitutions, or to differences in their surroundings. How potent may be the force of heredity to over-ride environment is most vividly seen when, as often happens, we find in one and the same family children of very diverse physique, intelligence, tem-

perament, and looks. In a sense, of course, the environment is all-powerful. Take away the whole fabric of civilization and place unlettered children to grow up on a desert island, and it will be centuries and tens of centuries before they could build up for themselves a civilization of their own, or think and act as we do. This only implies the obvious fact that environment and heredity are both essential, both what the scientist calls limiting factors. Modern man as we know him is impossible without a certain framework of environment; he is also impossible without a certain type of hereditary constitution. But within the bounds of one class, within one civilization, the environment is comparatively uniform. I am using the word environment in its widest sense, to include the framework of society, and the traditions which man has built up for himself—religions, philosophies, conventions, sciences—as well as the non-human environment of climate and physical surroundings; and the social and traditional environment is, over most of the globe, more potent than the natural. But within the bounds of any class, and, indeed, of the whole of a democratic civilization, heredity is of more importance than environment.

Now a child may have a good inheritance or a bad one. The fairy godmother of the old tales comes back to modern life as the chromosomes and the Mendelian factors or genes which they bear. There is to-day no more doubt that mental qualities are heritable than that brown hair or a hooked nose is heritable. Musical aptitude and mathematical talent in particular have been traced in their descent through member after member of a family, and there is no question but that general ability, intensity of emotion, and temperament, also follow the same laws in their hereditary transmission as have been worked out for more easily measurable

physical qualities. The simplicity of the relation, however, is masked by various facts. In the first place, it is highly improbable that a quality so complex as imaginative power or scientific ability depends upon a single Mendelian gene; apparently simple physical characters like stature or eye-color we are now finding to depend upon the coöperation of a large number of genes, and so it will be with mental qualities, too. But sexual reproduction works in such a way that at the origin of each new life there is a shuffling, a separation, and a new recombination of the hereditary factors of the parents. Only half the factors of either parent can find their way into the offspring, but the halving is accomplished differently each time. Thus new arrangements of the units occur. The units themselves, apart from occasional mutations, remain the same; but they appear in ever new constellations. Thus, in the present state of our knowledge, it is impossible even to try to predict the exact characters of an individual; although statistically we can make forecasts of extreme accuracy.

Much misconception exists as regards the number of gametes which come to maturity. In lower forms of life, there is an appalling waste of living material at reproduction. You remember Tennyson's lines about Nature—

"So careful of the type she seems
So careless of the single life";

and how the poet speaks of himself as

"finding that of fifty seeds
She often brings but one to bear."

But he was guilty of gross understatement! The oak will bring not one out of fifty, but one out of many hundred thousand seeds, to maturity. There are starfish which at

each act of reproduction liberate a population of eggs, each one capable of growth into a new individual, exceeding the human population of New York and London combined; and yet the race of starfish does not choke the earth.

In higher animals, the waste, especially on the female side, has been much reduced. The average woman only produces about four hundred ripe ova in the course of her life. On the male side, however, the wastage is even more beyond our comprehension. For each egg of the female starfish, the male will produce some million or so sperm, while even in a mammal such as man, for each sperm which successfully fertilizes an egg and becomes incorporated into a new life, many billions come to nothing.

And yet each sperm and each egg is alive; each contains packed within its microscopic body all the baggage which the human race needs on its journey through the generations; each is in a certain real sense as much a separate entity as the adult man or woman: so that, as Punnett put it years ago, the human race consists of four kinds of individuals—men, women, sperm, and ova.

With these preliminaries we can return to ask, what is the situation as regards birth-control? It is fairly plain. The regulation of the numbers of population, in some form or another, has been practiced by the great majority of the human race. As Professor Carr-Saunders has shown in his remarkable book on the Population Problem, every savage and primitive people of which we have any knowledge, almost every people of the early civilizations, and many peoples of the civilizations of to-day, deliberately regulate their numbers. Famine and wars are not and never have been sufficient. Either infanticide, or abortion, or various restrictions upon or regulations of marriage, have been practiced, with the effect of preventing or slowing the

natural increase of population. The quick growth of population which has followed every great rise in the level of civilization is the exception, not the rule; and the great and rapid increase which has obtained in Europe and North America since about 1800 is probably unique. It has been due to three main causes: first, the alteration in the methods of production which is summed up in the word *Industrialism*; secondly, the injunctions of the Christian churches in general and the Roman Catholic Church in particular; and thirdly, the great development of curative and preventive medicine. The precepts of the Church have always been similar; but in the past, war, famine, and disease have slowed if not stopped the full natural increase. *Industrialism* has meant that a greater density of population can actually be supported by a given area than was previously possible; and sanitation and medicine have seen to it that a much greater proportion of the natural increase of children shall survive and fill the vacant spaces.

But the vacancy has diminished; and *industrialism* has brought its own errors and tragedies. A continuation of the rapid increase of population did not seem so desirable in 1900, or even in 1875, as in the early days of expansion. Malthus was the first warning voice; and though his calculations and ideas were often wrong in detail, his fundamental principle remains sound. Various methods of birth-control began to be discussed between 1840 and 1870; but it was not until about 1870 or 1880 that technological advances put the matter on a really practical footing. From that day to this the practice has increased. Sir William Beveridge has recently analysed all the available figures, and finds no escape from the conclusion that the drop in the birth-rate which started at nearly the same moment in all white countries (except—a significant exception—those which are

predominantly Roman Catholic) owes its existence almost entirely to the improved practicability of birth-control. The same authority—than whom there is no greater living on the subject—prophesies that the population of Great Britain will, within the next century, cease to grow, reaching a stable phase like that seen in France to-day; and Raymond Pearl foresees a like consummation, though arriving a few decades later, for the United States.

It only remains to be added that while the practice itself appears to have become increasingly prevalent, the official attitude of the State towards it has never been favorable, while many organizations, especially "patriotic" and religious bodies, have bitterly opposed it.

The situation as it stands to-day is absurd. Here is a biological invention which if consistently and generally practiced must revolutionize society. At one stride it makes it possible for man to regulate his numbers and to enter once more upon a stable period in regard to population, but without reverting to any barbarous practices such as infanticide, and without going through the cruel ordeals of plague and famine. The practice grows obscurely but steadily; yet there is no overwhelming mass of opinion either to aid or to check it.

The chief trouble has been, and still is, that the matter is not discussed in any open spirit. Our first duty is to see what is at stake and then make up our minds without prejudice.

It is clear that population cannot continue to grow indefinitely. Already trouble, both international and domestic, is being caused in some countries by the need for population's overflow; not only that, but we are continually tumbling over ourselves in the attempt to catch up with the social problems which call for adjustment—only to find,

when we seem to have neared achievement, that the growth of population has brought a whole new crop of evils for our goodwill to tackle. On the personal side, only those who have been among the poor in big cities know how cruel the withholding of birth-control information can be. I have a friend in London who devotes a good deal of time to one of the voluntary birth-control clinics there: she tells me stories of the women who come there, working women on the lowest wages, coming diffidently and shyly, usually with their husbands' approval, to seek knowledge. Ten years married, seven children, five dead in infancy; four years married, one baby and two miscarriages; chronic ill-health, too much work to do, too many mouths to feed, another on the way—that is how the poor too often live. Mr. Wells wrote none too strongly of a recent refusal of the British Government to allow advice on birth-control to be given like any other medical advice in state-aided clinics. The refusal of Authority to allow men and women knowledge on the most fundamental facts and processes of existence is, he said, a tyranny which contradicts all the ideas underlying our civilization.

The further consequences are twofold. In the first place, quantity of births is always associated with quantity of deaths. In general, large families mourn more baby deaths: they involve a massacre of the innocents.

Further, from the standpoint of the community, quantity is not nearly so desirable as quality. Militarism and big business in its cruder aspects alone can want numbers as such—cannon-fodder or machine-fodder. Society wants men, not mere pawns in the game.

But that is not all: as matters stand at present, birth-control is actually practiced, but preponderantly by certain sections of the community and not by the others. In all

civilized countries the birth-rate of the upper classes—aristocracy, professional people, business men, and trades-people, is now much lower than that of the laboring classes. This is a new phenomenon; in earlier times the birth-rate was similar from top to bottom of society; the change became noticeable in the latter part of the last century, and is without doubt chiefly (though doubtless not wholly) attributable to deliberate birth-control.

At present twenty per cent. of the population in Great Britain gives rise to twenty-five per cent. of the next generation; and the average of this twenty per cent. is neither physically nor mentally as good as that of the other eighty per cent. We are thus confronted with a process which is retrograde in its effects—dysgenic instead of eugenic.

Before we can talk about eugenics, we must prevent this unequal multiplication. There is no prospect whatever of inducing the upper classes to abandon birth-control; our only hope is to equalize the increase throughout society by making birth-control universal and starting afresh on the new level.

There is of course no sacred right of a child to be born any more than there is a definite moment when it acquires a soul, immortal or otherwise. But it is remarkable how often the prejudices on such intimately biological matters as birth-control, when not caused by mere ignorance of the facts of nature, are due to this desire to force natural phenomena into unnatural categories of the human imagination, to insert the cuckoo's eggs of Absolute Rights and Values into the simple nests of natural reality.

The whole trend of evolution from lower to higher has been towards diminishing the number of offspring, but increasing the parental care, both before and after birth, which is bestowed on them. I think I am right in saying

that biologists are almost unanimous in demanding a rational birth-control as one condition of social advance.

Closely linked with this subject, as will at once be seen, is Eugenics. A rational birth-control is the necessary prelude to a rational eugenics. In the course of evolution the blind forces of natural selection have generated, in man, conscious knowledge and will, and to that conscious knowledge and will has been entrusted the task of progress, up till then blindly and painfully achieved.

Blind forces still operate in us, as we all know. The driving springs of instinct, the unrecognized power of repressed desires or fears, the consequences of a particular economic arrangement, undreamed of at its inception but working themselves out, the accidental but inevitable results of some form of social organization, the automatic urge of competition—these chivy and drive us, individuals and societies alike, whether we wish it or no.

On the whole, they seem to push us onwards, in the line of progress. But what is quite clear is that alone they cannot push us beyond a certain point. It would be more accurate to say that they cannot touch us at all except on certain levels, and these levels not the highest on which our existence moves. Our highest activities must be controlled and illuminated by consciousness; the upper reaches of our existence, in art, in morals, in intellect, those levels on which man is truly a man and not an animal—these are all unattainable except by the use of conscious reason, conscious will, or conscious emotion.

Thus, any true advance, any advance in quality of life, can only operate through consciousness. Through consciousness we become the trustees of the evolutionary process. This is the simple but glorious truth underlying eugenics.

Eugenics can become actual in a number of ways. We can improve the level of achievement by improving conditions and social organization. This is the gospel of ninety-nine out of every hundred educational and philanthropic bodies. But it is by itself an incomplete and even dangerous programme. It cannot raise the potentialities of achievement, as these potentialities were raised in the passage from reptile to mammal, from man's ancestor to man; and it cannot prevent degeneration of the stock.

To take the latter problem first, we know now, first, that harmful recessive genes are carried in the stock of any sexually-reproducing organism, perfectly harmless and without effect—so long as two similar ones are not dealt out to one individual after the shuffling that accompanies reproduction. It is on this account, and this account only, that the marriage of near relatives may produce ill effects. Inbreeding is not in itself bad; but, if there is in the stock any hereditary taint, due to recessive Mendelian factors, inbreeding will bring it to the light and to pernicious activity.

We also know that mutation, or actual change of hereditary factors, is slowly but continually occurring. We also know that the majority of such mutations are harmful—a result which we might have prophesied on the simple theoretical principle that it is easier to damage a complex bit of machinery, or throw it out of gear, than to improve it.

In nature, natural selection will operate against the poor combinations of existing characters, as well as the poor new-mutated characters, and they will thus tend to die out as soon as born. But the whole trend of human civilization is towards their preservation. The very existence of society means that natural selection operates more directly upon the social organism as a unit, less upon the single individuals of which it is composed. Philanthropy

has of late years conspired with modern medicine and modern sanitation to preserve ever-increasing numbers of individuals who would in less civilized times have died off in youth or infancy. There is a very real danger that the average quality of the population may be changed for the worse by the survival of the unfit—a danger that is made more acute by the fact, commented on earlier, that on the whole the undesirables multiply faster than the desirables. All the evidence, it is true, goes to show that the actual physique of the people of Western Europe, as measured by stature, by expectation of life, has increased during the historic period. But this improvement appears definitely to represent only a fuller realization of the innate potentialities that already existed and has been made possible by an improvement in the conditions of life. It is being now counterbalanced by the lowering of the average standard of potentiality. Especially serious is the low standard in the qualities of the mind.

The greatest shock of the war to far-sighted people was the revelation of the United States Army Intelligence tests. Even when various necessary discounts have been made, they showed that the intellectual capacity of the average American man was distinctly low. I have no doubt that similar tests in any other country would reveal a similar state of affairs.

The long and the short of it is that we have not yet thought seriously of the future of the race. We spend endless time and money in improving the breed of horses or sheep, we pay fancy prices for prize dogs or pedigree bulls; but we let the breeding of men shift for itself, until we are becoming a scrub herd of mongrels. The only practical thing that is ever done in connection with race is to offer prizes and bonuses for large families: by this

means we may encourage quantity, but often at the expense of quality. We neither attempt to improve the stock, nor even to prevent it from degenerating.

Moreover, there are no essential difficulties in the way of our second ideal, the prevention of racial degeneracy. The collection of statistics and the improvements in physical and mental testing are giving us reliable information as to the inheritance of all kinds of defects. Men like Davenport and Goddard have shown clearly that true feeble-mindedness is an inherited character, inherited often in the simplest Mendelian fashion; the work of places like the Psychopathic Laboratory of the City of Chicago is proving not only that emotional instability and disorder is at the root of a great proportion of crimes of violence, but that it runs in families in the most striking way. Morons breed morons, and neurotics of criminal tendencies bring others like themselves into the world; and we let them do it. The situation is aggravated when we find that on the whole these undesirable types have a higher fertility than the rest of the population, so that their relative numbers are tending to increase.

We have to make up our minds to a new step in human history: to the conscious control of reproduction. This is being done individually with birth-control: it must be done socially by what we might call mating-control. When we know that men or women are not only the embodiments but the bearers of hereditary taint and defect, we have no more right to allow them to reproduce than to allow a child with scarlet fever to be visited by all his school-friends. We are told that this infringes the sacred rights of the individual and prejudices the idea of personal liberty. Such utterances are but another example of the unfortunate tendency, apparently inherent in the primitive human mind, of demand-

ing and pretending to find absolute sanctions for ideas which are not in any sense absolute. If we talk of the divine and inalienable right of personal liberty, we are talking bunkum, and trying to transmute a practical idealism into terms of an abstract theology. Everyone knows, directly they begin to think about the matter, that what we call liberty is a compromise between the claims of the individual and those of the community, a compromise between abstract justice, selfish egotism, practical give-and-take, and social expediency. Before it was known that various diseases were infectious, the liberty of sufferers from these diseases was not curtailed; but immediately it was recognized that this liberty involved the infection of others, it was also recognized that the community had a perfect right to curtail liberty in that particular respect. In other words, the degree of liberty which the individual can possibly expect is and must be conditioned by what we know and think of the effects of that liberty upon others.

Undesirables can be prevented from reproducing their kind by permanent segregation. The advance of scientific methods has made it possible to secure the same result in a more humane and less expensive fashion; they can be sterilized by an operation which in the male at least is exceedingly simple. A beginning has been made in various lands. This country and Switzerland lead the way; but the numbers of such operations are as yet infinitesimal. What we want is a clear recognition that racial health is of equal importance with individual and social health; once this is gained, action will follow from the pressure of opinion. When it is realized that the defective germ-plasm, which the nations of the world pass on in the stream of life from one generation to the next, is certainly not less, and perhaps more, potent than bad physical surroundings, poor

upbringing, and defective schooling in filling our jails and hospitals, in causing social problems that need never exist, in calling for vast expense in mere cash, in diminishing the efficiency and happiness of the world in a wholly unnecessary way—once all this is realized, we shall not be so ready to allow a fancied right of a single person to inflict lasting injustice to the community. The curse of modern democracy is sentimentalism, which is to morals what bad taste is to art. It mistakes shoddy for the genuine article, and erects false values in place of true.

Bad taste often over-emphasizes the obvious but trivial at the expense of the essential—have we not just emerged from an age of over-decoration and under-planning? Sentimentality does the same. Bad taste has no sense of the rational congruity of some things, the hopeless incongruity of others—it does not think. I once saw a drawing-room “ornament” in the shape of a copy of the Venus of Milo with a clock let into the stomach! Sentimentality suffers from the same refusal to allow reason to break down watertight compartments or to allow it a hand in the shaping of an organic whole. Sentimentality clamored to hang the Kaiser as a solution of all after-the-war international problems. Sentimentality gives money to beggars without thinking whether an order of society which produces beggars may perhaps need changing. And sentimentality juicily rejoices (as I saw in the newspaper not long ago) over the “romance” of a marriage between two congenital deaf-mutes—without once reflecting on the crop that it was raising for the future.

We do not hesitate to weed our gardens. For God's sake, why do we hesitate to weed the garden of humanity?

If we once made up our mind to it, this negative, weeding kind of eugenics could be easily practiced. It must be

confessed, however, that positive eugenics, or the raising of the upper level, is not so easy. In the first place, though we can be perfectly sure that the same general principles apply to human inheritance as to inheritance in other animals, we know very little about the details, and cannot solve any of the more difficult problems so long as we cannot control human matings for the purpose: and this, even if it were desirable, is certainly not at present practicable. In the second place, any selection which we could practice, in any state of society at all resembling the present, would produce its results extremely slowly and inefficiently. Let us take an example from domestic animals. In fowls, it is desirable to secure high winter egg-production. This property appears to depend upon a number of Mendelian factors, hard to disentangle from each other; the easiest way to go about obtaining it would appear to be by simple selection. But the selection can be of two kinds—mass selection, or individual selection. In mass selection, all those birds with more than a certain record of production are taken and used *en masse* as parents of the next generation. With individual selection, on the other hand, single good performers are taken and bred from separately. When this latter method is adopted, it is found that some of the original high layers owed their good performance to some accident of diet or other extraneous circumstance, and not to the inherent qualities of their germ-plasms. Their offspring were only average or even poor performers. As a result of an actual experiment it was found that the effect produced by generations of mass selection was negligible, while individual selection, by enabling the impermanent and accidental effects of environment to be weeded out, at once and markedly and permanently raised the level. There was one relevant difference between this

flock and human society; with the hens, the whole breed had for some time been subjected to some form of selection for good productivity, so that the really poor strains had already been weeded out. In human society, most of the qualities which we prize the highest are not only complex, doubtless depending on numerous hereditary factors, but easily modified by environment and education. We all know how temperament and intelligence, for all that the basis for their potentialities is given in the germ-plasm, are profoundly responsive to training and surroundings. But in human society as at present organized, mass selection would be the only possible method to adopt. To attempt to reproduce the race wholly from a few thousand, even a few ten thousand, individuals, would for the present be unthinkable. We can do something, but very little, and that little only by running counter to some of the most cherished sentiments of our democratic age. We have got to stop pretending that comfortable mediocrity is our ideal, and that the average man is the god to whom the rest of the world must bring their sacrifices.

Already the conflict is making itself practically felt. With the growing demand for higher education, the consequent growing burden upon the academic profession, with the shift of emphasis from research to teaching, and the consequent growing cost to the state, the question is being asked (especially in this country, where the problem is perhaps most acute) whether the fact that a young man or woman desires a higher education is in itself a sufficient reason for allowing him or her to enter college, even if that college be a state institution in a democratic country. A noted educationalist at one of your most noted state universities told me the other day that he had raised that very point; and that in consequence the president had asked

to see him and had very pleasantly but quite firmly told him that this question should not be asked in public by a professor of a state institution. In the present state of public opinion that may be so. But the question will be asked outside, and the problem will not only remain but will grow more acute.

The younger Haldane has dealt with the question in its eugenic aspect in his pithy and amusing booklet "Dædalus". He does not believe that any substantial improvement of the human race could be made, not merely under our present type of social system, but with our present technical methods. He points out, however, that tissue-culture is in its infancy. Half a century ago, the idea of growing bits of animals outside the body would have seemed chimerical. To-day it is an every-day method. Even the tissues of old animals can be made to grow by the use of proper media, and cells from a chick embryo have been kept alive and multiplying for a time much greater than the maximum life of a fowl. What is to prevent us from devising methods which will not only enable us to grow reproductive cells in tissue-culture, but also to bring up the embryo outside instead of inside the body, substituting the incubator for the womb, and an artificial nutrient medium for the maternal blood? Such an idea, like all ideas which touch our feelings, seems at first not only impossible but impious. But Prometheus was thought impious in the past; and the most respectable evolutionist or practiser of birth-control is called impious to-day, by the perfectly sincere occupants of a thousand pulpits.

Whether impious or no, the possibility of such a technique would bring with it the possibility not merely of evolutionary advance for man, but of rapidity in that advance. A few hundred individuals could be chosen as the procreators

of a whole generation, and individual selection and conscious control would become practicable. Whether the mass of the population would consent to sacrifice direct parenthood for the sake of the race, and be content with adopted children or even a communistic nursery—that is another matter. But if ever such technique comes into being, it will bring with it a conflict on this, the most momentous question which humanity will ever have had to face.

Another matter connected with eugenics is the control of sex. Here, in spite of the mystery with which the subject has in the past been surrounded, all now seems plain sailing. The mystery is in its essentials no longer a mystery. We have been able to see in the diversity of plant and animal forms almost every conceivable stage of the evolution of sex; we understand in broad outline its *raison d'être*, its biological function; and we know the mechanism of its determination in higher animals.

As I pointed out in a previous lecture, sex is determined, in man as in all other mammals, by the sperm of the male. There are two kinds of sperm, one larger and one smaller; the larger is female-determining, the smaller is male-determining. Artificial fertilization is perfectly practicable; it was successfully employed in mammals by the Abbé Spallanzani in the eighteenth century. It remains now only to separate the two classes of sperm according to their size, and sex-control would be an accomplished fact. I cannot believe that this separation would present great technical difficulties—certainly none as great as were involved in the construction of an efficient phonograph, or a modern aeroplane. Yet these inventions were perfected in a few decades. I will venture to prophesy that in the matter of sex-control it will be only a few decades before the invention reaches the practical stage.

Then, as with all inventions, the question arises as to what use we shall make of it. With domestic animals, doubtless, the method will have immediate and important application. What a lightening of labor and anxiety to the stock-breeder or the fancier! But how will it be with man? Would it ever be desirable to risk upsetting the proportion of the sexes by allowing individual parents a free hand in choosing the sex of their children? I am inclined to think not, and to believe that the state should assume complete powers in regard to the question, allowing the method to be employed only in special cases.

But in special cases, what happiness it might bring! Who does not know families of six boys, or eight girls, in which the parents are pining for a child of opposite sex?

In any event, here as ever, the advance of knowledge brings humanity face to face with the need of new decisions.

Another allied problem which calls aloud for solution is the problem of race. You in this country know better than most peoples the difficulties attending the coexistence in one country of widely-divergent racial types. But the same problem in one form or another is to be found all over the world. In India, in South Africa, in South America, it is urgent: it may at any time become urgent in China, Japan, Australia, Equatorial or Northern Africa. Professor Gregory gave a thought-provoking study of the subject in his presidential address to his section at the British Association this summer. He came to the conclusion, with which I think most people would agree, that the best way of dealing with the problem of race is to prevent it from ever becoming a problem. Where practicable, nations should aim at homogeneity of race. Note that by race, here, Dr. Gregory implies only the broadest racial divisions. He is thinking of whites, blacks and yellows.

True that in many parts of the earth there has been mixture between these three main types; but that in no wise prevents the original dissimilarities from being any less important. In this, biology supports him. The so-called racial differences within one of these main divisions are few and of less importance. The average man too often makes the old mistake of confusing nationality with race. There is a British nation and a French nation; but no British or French race. The distinction is at once clear when we look at this country. The American nation is a very important reality, but God help the man who begins to try to define what he means by the American race!

America is naturally destined to expand for a longer period than Europe; but even you here in Texas, living in a period of the most rapid change and progress, must accustom yourselves to thinking of a stability of population as not only the inevitable, but also the desirable, last state of your country. Progress will then be measured not by counting heads, but by the advances man makes in his conquest of nature and in the discipline of himself—in the control of external forces and in the art of living. To achieve this fully, it is necessary to have a coherent population; that does not mean a uniform population, but one in which there can be free mingling of the different types, no alien elements or unabsorbed masses of people, and no large proportion of disharmonic combinations.

Viewed from this aspect, your immigration policy seems biologically wise; in a hundred years our descendants will probably see a fully unified white American population, with consequent dying out of the wild fears about foreigners and Bolsheviks which have swept this country since the war more violently than any other in the world. As Professor Pearl points out, the mere restriction of immigration is

probably more important for you than the proportions of the stocks which you allow in.

I say the white population. Of the colored problem I will not speak, because its solution in this country does not yet seem to be even in sight. In South Africa I hope we shall try segregation, the delimiting of areas for blacks and other areas for whites. In South America intermarriage and the creation of a mixed white-Indian-negro stock has been practiced. Neither of these seems practicable in this country, and time alone will show what can be done.

Before closing, I must try to touch on a few questions in which biology seems to throw light upon sociology.

If we study evolutionary progress, we find that the higher animals are all highly unified, all characterized by the possession of a centralized and dominant organ, through which the behavior of the whole is controlled. This organ is the brain; and not only is it the organ of control, it is also the organ of consciousness. Increase of intensity of mental power is also a part of progress. It culminates in the self-consciousness of man. So was generated the possibility of life on a new level, with new values; and the greatest men direct their activities preponderantly on this new level, living in a world of intellectual, moral or æsthetic values. From another angle, we may say that increase of intensity of mental process appears to be a necessary accompaniment of increased biological progress and increased efficiency of control.

Is there any application of this to the problems of society? I believe that there is, although many thinkers have denied that any profitable parallel can be drawn between the organism and society. It is perfectly true that there are vast and important differences. For instance, it is clear, both to immediate feeling and to careful analysis,

that the individual is of higher essential value than society: in other words, that, although society must be preserved when it is threatened, because organized society is necessary to civilized existence, yet in the long run society exists for the individual, not the individual for society. Yet only by an efficient carrying on of the business of society as society, as a unity or individuality of a higher grade than man, can individual man realize his potentialities to the full. The solution lies in man's plastic mind; he can turn at will from an independent individual to a mere cog in the machinery of society and back again. He can thus, for part of his time, devote himself to the ends of the social organism, and then reap the harvest in his capacity as an individual organism. In so far as men and women are devoting themselves to the workings of society, just so far is the society which they compose a true organism; and the laws which we find applying to other organisms will apply to it.¹

Not only is there a dominant controlling organ, in the shape of the brain, in adult higher animals, there are dominant regions in development. As I pointed out in my first lecture, the process of differentiation, the development of something out of nothing in the developing embryo or the regenerating animal, appears to be dependent on the presence of a region of great activity. How great activity of one tissue stimulates other more passive tissues to the activity of differentiation, we do not know; but it appears to be a fact.

Both these phenomena seem to have their counterparts in the working of human society. In so far as society acts as a single organism, it must have an efficient controlling

¹The problem is, of course, complicated by the fact that the individual human being is a higher type of individual than society, the aggregate of which he forms part—the reverse of what obtains in most organisms. What I have stated is true, but only within the limits mentioned.

organ. This is most clearly seen in time of war, but is just as much present, though not in so clear-cut a fashion, in peace as well. Public opinion, the press, the legislature and the executive administration, universities, bodies like national research councils and churches—these together (though with considerable friction) operate as the brain of society. And as regards differentiation, which here means properly directed change, new intellectual or social evolution, it is an obvious rule that it is brought about by exceptionally active minds which act like a ferment and set others to thinking and acting in new ways.

I think it would be well if we asked ourselves whether our present brand of democracy is calculated to give us the best organs of social control and differentiation.

The advantage of democracy is the raising of the condition of the mass of the people to a good average. The curse is the tendency to pull down what is above the average to the level of the average's mediocrity.

A democracy of material opportunity freely surrendering itself to the guidance of an aristocracy of thought—that seems to me to sum up pretty closely the biological ideal for society. But we are far from it yet.

There are scores of other ways in which biology can now, or will eventually, affect practical life. The science of genetics, an infant but an infant Hercules, is bound in time to change the practices of stock-breeders; the present pedigree system has its many advantages, but it has its genetic and economic absurdities, in the emphasis on an old aristocratic pride of ancestry quâ ancestry, irrespective of scientific analysis, and in the fantastic prices given for pedigree prize-winners.

Greater knowledge of physiology will doubtless enable us to modify the processes of our bodies more in accordance

with our wishes—to stimulate our faculties when we need high-tension work, but without evil after-effects; to relax them without the use of harmful soporifics.

It seems clear that temperament, even more important than pure intellect in achieving success, is largely an affair of the balance of the various glands of internal secretion—thyroid, pituitary, reproductive, adrenal and the rest. It may well be that the applied physiology of the future will discover how to modify temperament. Many men of sedentary life came back from the war with altered temperaments. Probably, to use Cannon's phrase, they had "discovered their adrenals"—the violent activities into which they were forced made demands upon the adrenals and other glands which their previous life had never done: the glands responded by increase of function, and a new equilibrium was set up which they preferred to the old; and consciously or unconsciously they refused to let it fade out when they returned, but adjusted their mode of life so that it was continued on a different plane. We are sure to discover more and more of the means of playing on this complex system within us and eliciting from it the vital harmonies which we desire.

We are likely to be able to apply plant breeding to create new forms of life which will work for us in unsuspected ways. As primitive man learned to use yeasts to make his alcohol, bacteria to manufacture vinegar and cheese, scientific man is certain to find ways in which he can build living factories, as well as dead, to supply his wants and luxuries.

But I must close. Let me remind you that while pure science will make discoveries so long as she exists, while technology will apply those discoveries so long as profit is to be made out of their application, it is in the long run the average man and woman who decide *how* that application

shall be made. Whether the discoveries of science will in the ultimate event be beneficial, as those of us trust who believe in progress, or whether they are leading the human race to destruction, as many sincere and many far-sighted men assert—that will be decided by the use to which the human race decides to put them. In themselves, apart from their intense personal value to their discoverers, and to others on the plane of pure intellect, they are neutral, like any other tool.

Let me also remind you that humanity is always mistrustful of any radical change, and especially so in any field which touches their feelings and their instincts. All large biological discoveries are bound to affect human feelings and instincts; and so, as Haldane points out, they will always by a great proportion of mankind be greeted as impious, immoral, or indecent. Look at the myth of Prometheus; remember the edicts against the practice of dissection by the early anatomists; remember the storm of obloquy that broke on Darwin's head; look round to-day and see what pious curses are being launched at birth-control and eugenics; and try to apply the needful psychological corrective to any immediate reaction you yourselves may feel towards any new project based on biological knowledge.

Recall that, as Mr. Trotter somewhere puts it, when we find ourselves holding an opinion with particular tenacity, that is probably a sign that we are holding it on irrational grounds; and remember that now in the fullness of time, the cosmic forces by which we were generated have made us the trustees of progress, and entrusted to our conscious free-will the future course of evolution.